



**Ronald Todd**

## Design and Technology Yields a New Paradigm for Elementary Schooling

Over the past decade, our profession has turned increased attention to the nature and role of problem solving as an important aspect of technology education. Articles included in our professional journals, presentations made at our professional conferences, and proposals funded by supportive agencies and foundations attest to this shift in our pedagogical focus and efforts. Problem solving, however important, is too limited, and our efforts in improving technology education will be better served by attending to the larger arena of human endeavor called “design.” This new perspective is represented in the ongoing work of the Technology for All Americans Project (International Technology Education Association, 1996), which seeks to establish new standards for technology education. In these standards, design cuts across all grade levels, starting first with “design and make” at the elementary level and moving on to “design and produce” at the secondary level.

The progress made in this country in the understanding and application of design as a part of technology education is directly related to the support that has been provided by colleagues abroad, especially those from the United Kingdom. The implementation of “design and technology” has led to the use of the concept of D&T that goes beyond a linking of the two terms and suggests a synergy that enriches both design and technology as they inform and extend each other. In this article I will try to portray D&T as a new and important approach, a new paradigm, for teaching and learning of technology as an essential subject for all students, at all grade levels.

As discussed in more detail by other authors (e.g., Kirkwood & Foster, 1997; Raizen, Sellwood, Todd, & Vickers, 1995), schools are not working for a large portion of our students who see education as a mindless and meaningless activity. Education faces a need for drastic change—a need that can be fulfilled, in part, by the implementation of a new paradigm for schooling. D&T can provide that paradigm—a paradigm that discards the “front-loading” of theory before any application of knowledge is permitted. The D&T approach can be used to help concepts and theory emerge from practice. This seemingly modest suggestion could change schooling as we have known it while also attending to some of the demands for improvement reiterated in the

countless studies that have emerged over the past decade and a half.

Within the D&T approach, teachers and students work collaboratively in learning and doing. As part of this approach the children perform as designers and developers—the teachers as mentors and guides. Design thinking, fostered from kindergarten upward, includes investigating, creating, planning, making, testing, improving and evaluating. Design activity can foster group interaction and cooperation, perseverance, resourcefulness, divergence and self esteem—all fundamental preparation for life and work in the 21st century.

Design and technology activities would nurture new ways of thinking and doing with increased valuing of knowledge and practice. Design and technology would deliver reflective thinking and doing to even the youngest of students. Design and technology education would engage students in applying what they have learned to new circumstances and to use those new settings for collecting data on their research and experience. The students would reflect on their data that would lead to making approximations, proposing solutions, iterating improvements and continuing the process by assessing how well all of this has worked. The design and technology spiral would provide alternative ways of thinking that places importance on multiple answers, that make failure a normal and respected part of learning, and that support students in knowing more about their research and developments than anyone else, including the teacher. (Todd, 1997)

### The Design and Problem-Solving Process

Design and problem solving have a variety of meanings for different people in different subject areas. In science it is known as the scientific method, in design and technology it is best recognized as the design loop, and in mathematics it is seen as the setting of a task within a given context.

For our purposes here, problem solving is identified as a structured component within a general investigative approach to learning. It is compatible with a defined methodology—the “design process”—long recognized by designers, engineers, and technologists. This perspective appears to extend across those countries that have established a D&T component within their school curricula.

The design process model, shown in Figure 1, is representative of the problem-solving approach being implemented internationally in technology education programs (Hutchinson & Hutchinson, 1991). The design process is often depicted as a “design loop” with differ-

*Dr. Todd is Publisher of TIES Magazine and Director of Project UPDATE at The College of New Jersey, Trenton. He is a member of the Alpha Rho Chapter of Epsilon Pi Tau and has received the Honorary's Laureate Citation.*

ent tasks to be accomplished. The tasks, too often seen as steps, should be considered as suggestive rather than prescriptive. In actual use there will be marked differences in how individuals pursue a task and implement the process.

The design process should be seen as interactive and iterative as students move between active and reflective modes of behavior. The design process can help students organize and structure their thinking. Throughout the process there is always the problem of the moment as well as the more central problem or objective. It is important that students become familiar with the model but not attempt to follow it rigidly, consequently impeding the learning process. With experience, students can move through the process, shunting back and forth between active and reflective modes as appropriate, but still arriving at a sound and workable solution. Many practicing designers consider the stages of testing and evaluation as one of the most likely starting points in the design process. They assert that most products are variations or improvements of existing models. Our experience has shown that students can successfully enter the process at different points in the process and not be restricted to the artificial starting point of identifying the problem to be solved.

### Escalated Demands on Elementary Education and Teachers

Over the years, as with education generally, the demands on elementary education have increased significantly. The elementary curriculum and the elementary teacher are expected to accomplish more than ever before. The move toward establishing standards of learning can be viewed from several per-

spectives. One can consider the standards as an effort to clarify what should be taught, or at least achieved, in the process of schooling. One could also consider the standards as a means of making teachers more accountable for what students actually learn. In any event, the introduction of standards of learning represents a continued escalation of responsibility for elementary teachers.

The responsibilities now extend far beyond the transmission of knowledge, including accepted roles, such as enhancing students' personal and social development; more demanding roles, such as increasing higher level (critical and creative) thinking; and now questioned roles of teaching of attitudes and values. These are but a few of the growing list of responsibilities of elementary teachers.

For purposes of this discussion, I would like to focus attention on five general categories that represent the escalation of instructional responsibilities: engagement, integration, inclusiveness, authenticity, and empowerment.

### Engagement in Learning

By engagement, I refer to the increased attention given by students to what they are learning. There is a growing body of research that indicates learning can be increased if students spend more "time-on-task." There is a strong and significant connection between learning and engagement time. This means that students who spend more time thinking about the content and process with which they are engaged will learn and retain more than students who spend less time engaged.

One of the areas where technology education has impacted the most has been on individual students. For many students, the practical subject has been an "island of meaning"

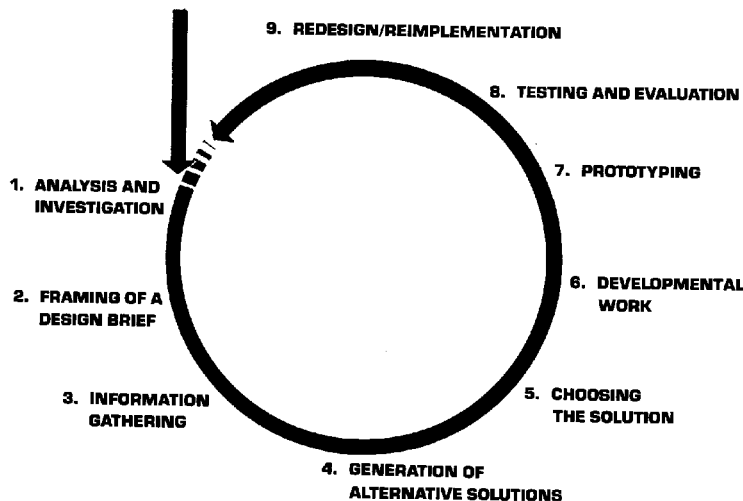


Figure 1. The design process model (the design loop).

in a “sea of nonsense” in their schooling, particularly those who found the standard classroom fare to be dull and of little consequence. The same remains true for technology education today, especially when enriched with the inclusion of design and problem solving. It is not a surprise to those of us in the field that students who see little relevance in what they study often find the activities of technology education to be exciting, engaging, and meaningful.

The use of D&T can increase engagement in learning by helping to:

- improve student attendance.
- shift students from passive to active learning.
- provide minds-on as well as hands-on learning.
- help balance grounded/practical and ungrounded/theoretical knowledge.
- disprove the myth that young children have short attention spans.

### **Integration of Learning**

There is a great deal of talk about the integration of learning, but there is little evidence of integrative practice. Many elementary teachers, guided by common sense and personal experience, use “across-the-curriculum” approaches to related subject areas. They indicate that such an approach can help students learn and retain new knowledge more effectively. More recently, a compelling argument has been made to reduce the “decontextualizing” of the knowledge of what students are expected to learn (Farnham-Diggory, 1990; Resnick, 1987).

Unfortunately, the continuing move toward the separation of disciplines and departmentalization of subjects promises to make the application and integration of learning across subject lines increasingly difficult. The new “paradigm” for schooling as implemented through D&T, however, could provide children with opportunities to learn and use knowledge in an integrated and supported fashion. Our experience in Project UPDATE has shown that the D&T approach can be used to deliver instruction across the curriculum through integrated, realistic, and developmentally appropriate experiences for children—experiences that are expansive and rich rather than restrictive and impoverished.

There is growing evidence that the past practice of reducing curricula and learning to their simplest, discrete parts is proving ineffective with students and teachers alike. Students can and do attend to activities over long periods of time if the activities are engaging.

We need only witness children involved in selected play activities of their own choosing, such as using construction models, dungeons-and-dragons, and computer games for evidence of long-term attention and extended time-on-task.

Good teachers tend to reject curricula developed by others and prefer plans for which they feel some ownership. Undergirding the desired involvement in complex planning and learning are new curricular and instructional strategies such as scaffolding and fading (Farnham-Diggory, 1990), and contextually appropriate curricula and curriculum mapping (English, 1988).

Elementary teachers are generally prepared to teach across curricular lines through such integrated approaches as “reading across the curriculum.” Teachers generally and elementary teachers specifically, however, have had only modest experience in science and mathematics and little, if any, in technology. This lack of experience not only makes integrated teaching of these subjects difficult, but leaves teachers with inadequate constructs for understanding and teaching about science and technology. Teachers, therefore, develop their own constructs that provide “functional explanations” of the real world, but these constructs may be closer to myth and magic than to founded constructs in science. Constructs based in myth and magic will not only interfere with integrated science and technology, but will result in “poor” science as well.

The need to integrate science, mathematics, and technology is captured in the following statements from the *Benchmarks for Science Literacy* (Rutherford & Algren, 1993) of Project 2061.

Project 2061 promotes literacy in science, mathematics and technology in order to help people live interesting, responsible, and productive lives. In a culture increasingly pervaded by science, mathematics and technology, science literacy requires understandings and habits of mind that enable citizens to grasp what those enterprises are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments and uncertainties. (p. XI)

Project 2061 underscores the need to integrate separate subjects and particularly science, mathematics, and technology. The utility found in linking the three subjects helps students apply what they have learned to practical situations. Through that practice of

application essential to the D&T approach, students can learn even more. Thus, technology education, delivered through design and problem-solving activities, can play a major role in enhancing the utility of science and mathematics for students.

The emerging results from Project UPDATE strongly suggest that D&T activities help students attend more to mathematics and science. Teachers report that they are able to hold student attention on learning and applying math tasks as students engage in planning, making, testing, and improving the projects that they have designed. Similarly, concepts of science, especially the physical sciences, can be introduced more effectively through the products, systems, and environments the students design and make.

Finally, the opportunity to use science and mathematics concepts in practice appear to help students and teachers develop concrete examples that can then be used to relate those concepts to other new circumstances. For example, as students engage in design and make activities related to playground equipment, they can apply and learn a range of important concepts, including size, movement, speed, diameter, circumference, force, energy, and acceleration. Because of this active involvement, these students will view these concepts with an insight unlikely for more passive learners.

The use of D&T contributes to the integration of learning by helping to:

- increase attention to science and mathematics.
- increase opportunity to apply science and mathematics.
- implement teaching and learning across the school curriculum.
- link in-school and out-of-school experiences.
- introduce and use adults in the classroom.
- reduce decontextualized learning by applying knowledge in meaningful contexts.

### **Inclusiveness of Instruction**

Recently, elementary education has turned more to including all students than to establishing programs designed to deal with special populations. The current practice places attention on ensuring access of quality education for all students while also ensuring that selected groups are not relegated to segregated and unequal education.

In research on student assessment in the United Kingdom, it became apparent that students at all ages could perform at a level

higher than expected. One aspect of that research is of particular interest to those of us involved in educational change as it addresses the problem of increasing the involvement of young women in science and technology studies and careers. The research on assessment of the technology-related work of students found that, in selected instances, girls scored as well as, and in many cases better than, boys. The key factor in the success of girls with technology content and skills was one of *context*. If problems and activities emerged from contexts that made sense to the girls, they fared very well when compared to boys. If, however, learning and assessment activities were initiated without setting a context, girls did poorly relative to boys.

Unfortunately, science and technology activities are often initiated with little or no context of meaning. Certainly this appears to have been the case in the kind of testing traditionally used in this country. From the growing experience in implementing D&T programs, the assumed lack of ability and interest of girls in science and technology may stem more from the collective naiveté in designing of instruction and assessment activities than from what young women can actually do in these fields of study. A greater understanding of the role of “contexts of meaning” will be essential if we are to unleash the scientific and technological talent of all students, girls and boys alike, for their own benefit as well as the future benefit of this country.

The use of D&T contributes to the inclusiveness of instruction by helping to:

- increase attention to gender and equity.
- attend to special “challenged” students.
- enhance cooperative and collaborative learning.
- attend to cultural diversity.
- disprove the myth that technology is for only a few.

### **Authenticity of Activities**

Over the past decade and a half, there have been many reports probing the problems of schooling in this country. The list of what ails us in education is long and even depressing. Some of the recurring observations of those studies are represented in the perceived lack of meaning of (a) what students are expected to learn, (b) the activities the students pursue, and (c) the testing used to determine what they have learned. Increasingly, we hear the concept “authentic assessment” in use in educational discourse. Less frequently, but equally important, are references to authentic activities and content.

*Project UPDATE (Upgrading Practice through Design and Technology/Engineering Education) is a K–6 effort across six states, supported, in part, at The College of New Jersey by the National Science Foundation, with the intent of using D&T as a means of integrating science, math, and technology for elementary students.*

Historically, the focus on technology education has been on the products or projects that students produced. In the United States, the products served as vehicles for helping students gain knowledge and skills related to the content of technology. The skills were focused largely on manipulative and analytic capabilities with little attention given to the skills of design and problem solving. The reverse was largely the case in the United Kingdom. The products developed by students served as vehicles for helping them gain knowledge and skills in the process aspect of technology. The content of technology was generally limited to what was needed to complete the problem in which the student was engaged. Usually the focus on content or process was taken at the expense of the other, resulting in a lopsided approach to the study and engagement with technology.

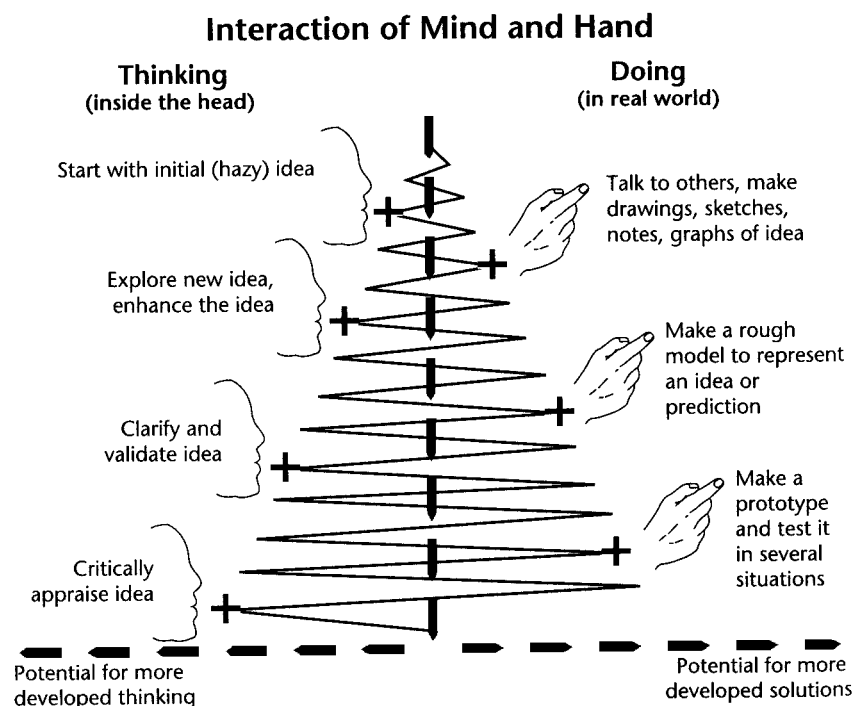
Bringing these two aspects of the field into balance was intended to provide an involvement by students in the design and problem-solving process that was supported and enriched by an established and articulated knowledge base of technology. The integration of the process and content of technology placed considerable importance on how students were to be engaged in the learning and doing of technology. This involvement is characterized in the interaction of mind and hand model shown in Figure 2 (Kimbell et al., 1991).

Figure 2 identifies the essence of D&T as

the interaction of mind and hand—inside and outside the head.

It involves more than conceptual understanding—but is dependent upon it, and it involves more than practical skill—but again is dependent upon it. In design and technology, ideas conceived in the mind need to be expressed in concrete form before they can be examined to see how useful they are. (Kimbell et al., 1991, p. 20)

By placing the interactive process at the heart of D&T, products are seen as supportive rather than central to that process. Giving more attention to the thinking and decision-making processes resulting from engagement with these products shifts more balanced attention to the “why” and “how” pupils chose to do things rather than “what” they chose to do. The pupils’ thoughts and intentions become as important as the products that result from them. Students often believe that from the very start of an activity, they have worked out a complete solution in their mind and will set out to translate that idea into final form. This seldom, if ever, is satisfactory because they cannot mentally sort out all the issues and difficulties in the task let alone reconcile them into a successful solution. Basically, the students will actually have formed a hazy notion of what a solution is that can serve as a crucial starting point for them. But it is only a starting point, and to enable the idea to develop, it is necessary to drag it out of the mind and express it in real form.



**Figure 2.** The interaction of mind and hand model.

The use of D&T can contribute to authenticity of activities by helping to:

- provide new means of attending to assessment.
- provide learning experiences that have meaning for students.
- provide learning that supports “constructivism.”
- disprove the myth that technological activities are only hands-on in nature.

### **Empowering of Students**

The concept of empowerment has been around for a long time, but it has only recently been applied to schooling. By empowerment, I refer to the capability of the curriculum and teaching to help students gain insights and skills that will help them make choices and decisions. These are seen as essential if students are to develop their capabilities for continuing what is often called lifelong learning.

Consider the following example and the level of thinking in which the young students were engaged. In one of the classrooms involved in Project UPDATE, third graders were being introduced to the D&T approach through problems set within the context of the school playground. The class was visited by Mike Ives, a technology education specialist from Her Majesty’s Inspectors (HMI), an agency in the United Kingdom whose primary purpose is to assess the quality of classroom teaching and learning. Mike talked with the children, often sitting on the floor asking them well-phrased and penetrating questions.

Mike became very interested in a working list on the chalkboard titled “Criteria.” Through his questions, he found that the criteria related to the work of the children who were designing a school playground. It was obvious that the title and four of the terms were written by the teacher. Two other terms, “safety” and “fun,” had been added by the students. Mike commented, “Blimey! Criteria is a pretty big word. What does it mean anyway?” One of the girls, not considered an outstanding student, rolled her eyes up and to the left in an obvious searching manner, “Criteria, yeah ...those are the rules and guides we use to see if we are making good decisions.” Later Mike commented that in his years of visiting schools throughout Great Britain, that was as good a working definition of criteria that he had ever heard. What was surprising was this comment came from a student of questionable, or at least underestimated, ability.

The use of D&T can contribute to empowering of students by helping to:

- provide opportunities for improving student self-esteem.
- add more learning experiences that have meaning for students.
- introduce experiences that support questioning and “constructing” of learning.
- provide experiences that enhance flexibility and adaptability of students.
- allow students to take risks and “fail” and learn from these.
- disprove the myth that students will not take charge of their learning.

### **Reactions of Elementary Teachers to D&T**

The effects of technology education and the D&T approach on individual teachers take several forms. Statements such as the following frequently emerge when teachers are asked why they adopted this new subject and approach: “I had made a decision to get out of teaching.” “I was burned out, bored, ready for something different.” “Teaching through a design and technology approach has made education exciting and worthwhile again.” “Technology education has breathed life back into my professional career.”

When asked what effect technology education and the D&T approach have made on their teaching, teachers respond with such statements as the following: “Using the design and technology approach has made it easier for us to collaborate on cross-curricular and cross-grade projects.” “The activities are more exciting for me and my students.” “The parents love what we are doing and the excitement that their children show when they come home.”

Finally, consider the personal observations made by two outstanding teachers—one a teacher of autistic students, the other a science support teacher. Kathy, the teacher of autistic students, observed, “This is the first year that I used the design technology approach with my class of autistic students, and the school counselor and I were amazed at the advances the students had made—the most improvement on the year-end tests ever.” Bill, the science support teacher, who had previously won a White House Award for Excellence in Teaching, commented, “I love science and I have always enjoyed it, but after learning this design and technology approach, I’ll never be able to teach science the same way again!”

### **General Observations on the Acceptance of D&T by Elementary Teachers**

In the assessment of Project UPDATE, elementary teachers showed mixed reactions to the concepts and practices of D&T and their

introduction into the elementary curriculum. Through our experience, it appeared that with a supportive administration:

- approximately 20% of the teachers in an elementary school are ready to adopt a D&T approach, almost immediately.
- an additional 50% of the elementary faculty could be converted to teach through a D&T approach if supported by a sustained in-service training program.
- elementary teachers see D&T as a means of helping them engage their students in critical and creative thinking.

There are problems, however, and some elementary teachers appear to be intimidated by D&T. They have concerns regarding:

- increase of noise and mess in their classrooms.
- lack of D&T resources and facilities.
- additional work the approach demands, especially initially.
- lack of training for teachers.
- lack of understanding of administrators.

### **Closing Notes on D&T and Change in Classrooms and Schools**

From our experience through Project UP-DATE, classrooms change as technology education is implemented as part of the learning experiences for students. As observed by teachers, (a) their classrooms become more diverse and exciting, (b) the activities become more engaging and demanding—for teachers and students alike, (c) the curriculum becomes more integrated and meaningful, (d) the evaluation becomes more authentic and productive, and (e) the students become more coop-

erative and sharing. And, finally, the classrooms do become more noisy and messy.

Visits to classrooms where the D&T approach was being used found students actively using a range of materials and resources. Working alone or in small groups, the students often were engaged in activities quite different from their classmates. Teachers were asked about this diversity of activity and the short attention span of students. “Doesn’t all of this make the classroom unmanageable?” The teachers admitted that they had to learn to deal with the increased noise and activity. They also grew to realize that what students were doing and the questions they were asking were often more important than what the teacher had to say. The teachers actually laughed at the idea that students have short attention spans. They know the “common knowledge” that students will not stay engaged for extended periods of time is wrong. “A major problem we have is to get students to disengage and to move on to other things, such as lunch and recess.”

Change within a school or across a school system is far more difficult than implementing change in a few classrooms. Some large-scale changes have started from individual teachers working alone, but this is the exception rather than the rule. The scope of the work that lies ahead in implementing D&T-oriented activities in elementary classrooms is massive. The opportunities for installing technology education as an essential component of schooling for all students are equally massive.

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